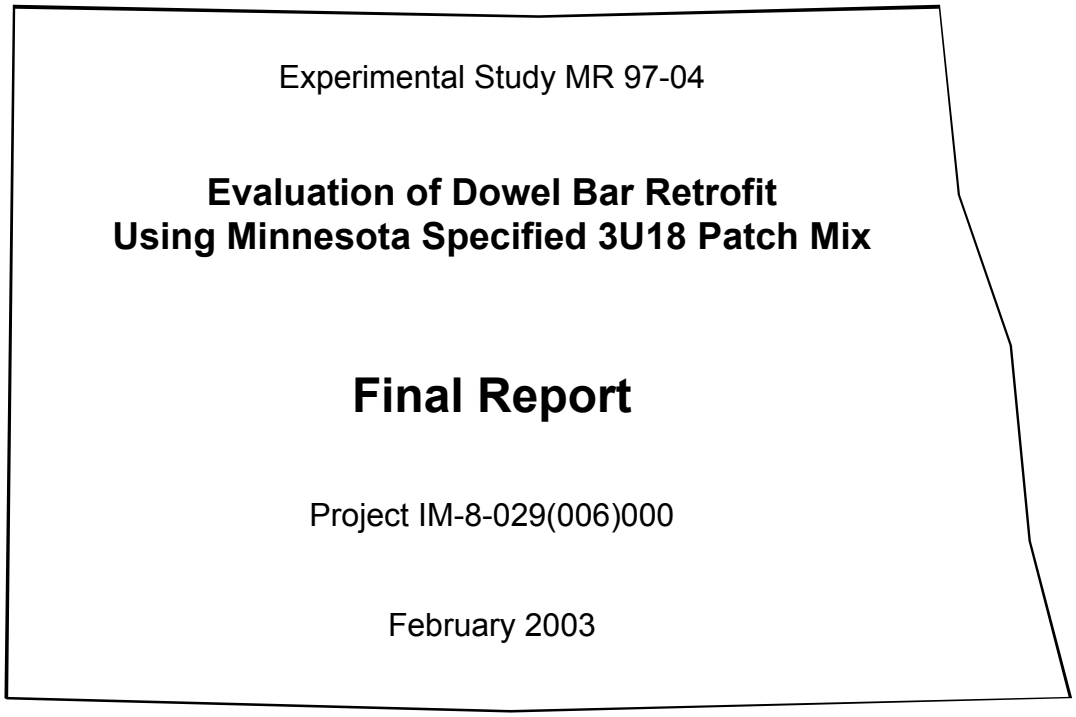
NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study MR 97-04

Evaluation of Dowel Bar Retrofit Using Minnesota Specified 3U18 Patch Mix

Final Report

Project IM-8-029(006)000

February 2003

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
Website: http://www.discovernd.com/dot

DIRECTOR
David A. Sprynczynatyk, P.E.

MATERIALS AND RESEARCH DIVISION
Ron Horner

Experimental Study MR 97-04

Evaluation of Dowel Bar Retrofit
Using Minnesota Specified 3U18 Patch Mix

Final Report

Project IM-8-029(006)000

February 2003

Written by
Curt Dunn/Bryon Fuchs

Disclaimer

The contents of this report reflect the views of the author or authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not reflect the official views of the North Dakota Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

TABLE OF CONTENTS

Evaluation of Dowel Bar Retrofit
Using Minnesota Specified 3U18 Patch Mix

Objective

The objective of this study was to evaluate the construction methods and performance characteristics of Minnesota specified 3U18 when used as a patch mix material on dowel bar retrofit projects.

Minnesota specified 3U18 is a patch mix material that the state of Minnesota has used on dowel bar retrofit projects.

3U18 patch mix was one of two patch mix materials used on a dowel bar retrofit test section constructed by the North Dakota Department of Transportation (NDDOT) in 1995. This was part of project IM-6-029(022)186. The prime contractor was Highway Services Inc. The other patch mix material was a proprietary product called Patchroc 10-60. Shortly after construction, however, signs of shrinkage cracks began occurring within the 3U18 patch mix itself and along the border between the patch mix and the existing concrete. It was uncertain, at the time, whether the distresses were caused by construction practices or from a mix design problem. As a result of its questionable performance, Minnesota specified 3U18 patch mix material has not been used on subsequent dowel bar retrofit repair projects.

Scope

During the 1997 construction season, the NDDOT performed a dowel bar retrofit on faulting concrete joints along a section of roadway on I-29 south of Fargo, North Dakota near the South Dakota border. Progressive Contractors Inc. (PCI) was the prime contractor for the project. Patchroc 10-60 patch mix material was used exclusively on the project.

During construction, PCI proposed, to the project engineer, to place a small test section involving the use of 3U18 patch mix material. A spokesman for PCI informed the NDDOT that they have used the 3U18 patch mix material in dowel bar retrofit projects in other states with good success. Upon approval by the NDDOT, a test section was installed.

The NDDOT evaluated the Minnesota specified 3U18 patch mix material for a period of five years. Items evaluated were:

- Construction methods in mixing and placing the 3U18 mix and how they compare to those used on the experimental project constructed in 1995.
- Evaluated the performance of the 3U18 patch mix and compared to the mix used in the experimental project constructed in 1995.
- Compared performance of adjacent Patchroc 10-60 sections with that of the 3U18 patch mix sections
- Percent load transfer across the joints where dowel bar slots contained 3U18 patch mix.

Location

Project IM-8-029(006)000 (SB) is located on I-29 from the State Line north approximately 11.3 miles. The small test section containing the 3U18 patch mix was located near reference point 7 and runs south for three joints. Eighteen dowel bar slots were placed. Refer to Figure 1 for the project location on the next page.

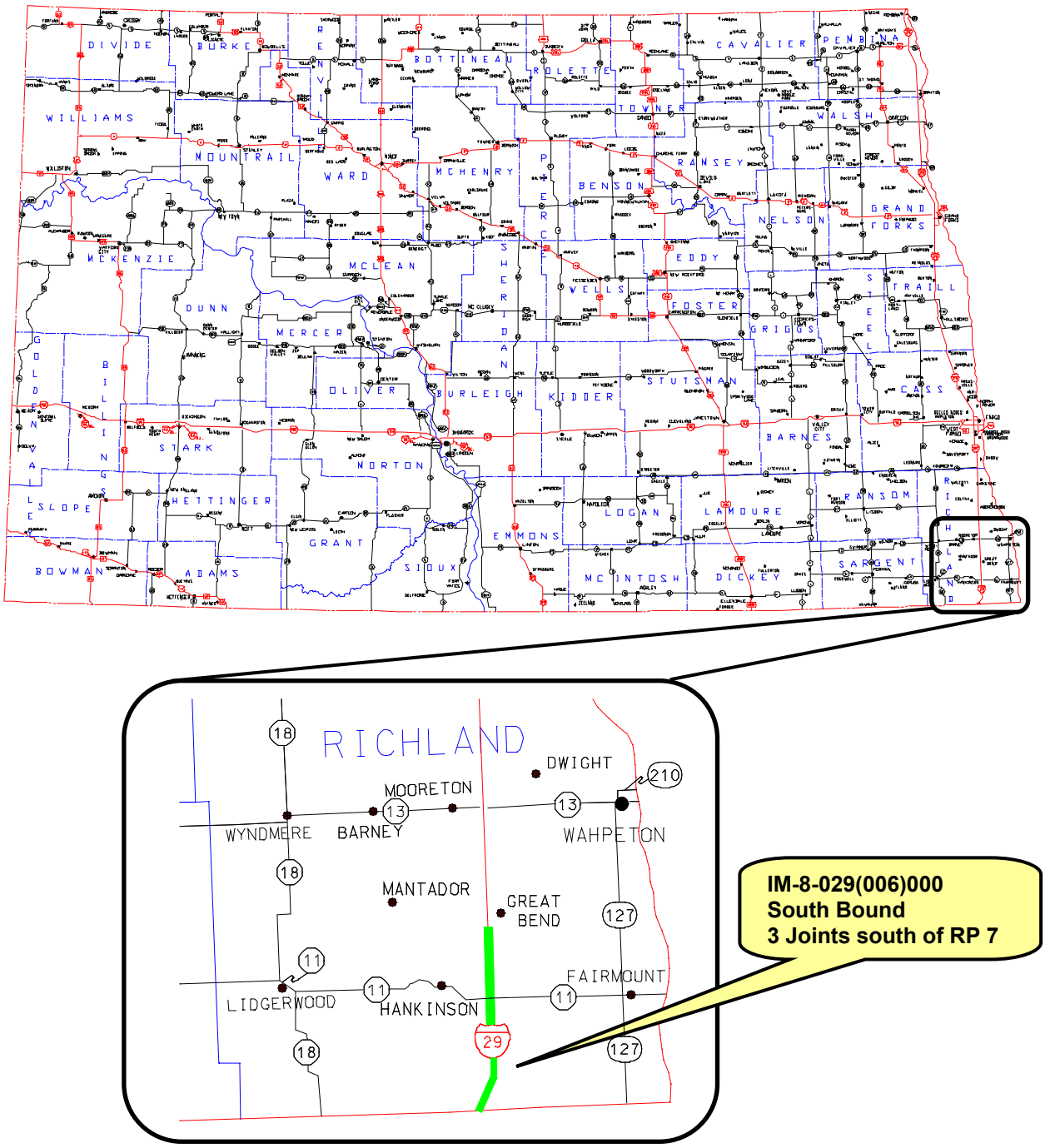


Figure 1 - Project location.

Project History

Construction

Table 1 shows the history of the pavement section from the South Dakota State Line north 11.3 miles (SB).

Year Constructed	Type of Construction	Depth (in.)	Roadway Width (ft.)
1975	Grade		48
1976	Aggregate Base	2.0	43
1976	Plant Mix Bit. Base 85-100	2.0	41
1976	Non - Reinforced. P.C.C.	9.0	27
1976	16 Foot Joints		
1976	P.C.C. Shoulders	9.0	10

Table 1

Traffic

Table 2 shows the one-way traffic estimates from the State Line north 11.3 miles (SB).

Year	Passenger Car	Trucks	Total	Max Hour	Rigid ESALs
1997	1,325	390	1,715	175	543
2000	1,500	525	2,025	203	672
2003	1,785	465	2,250	225	590

Table 2

Design

The gradation and mix design, used in this test section was obtained from the Minnesota Department of Transportation (MnDOT) and is listed below.

The following mix design was used for one cubic yard of 3U18 patch mix:

Cement (Type 1)	850 lbs
Water	295 lbs
Sand	1335 lbs
Aggregate	1350 lbs
Air	6½% ± 1½ %
Water reducer/accelerator	

The coarse aggregate gradation consisted of:

Sieve	% Passing
3/8"	100
#4	70-95
#50	0-5

The sand gradation consisted of:

Sieve	% Passing
#4	95-100
#8	80-100
#16	55-85
#30	30-60
#50	5-30
#100	0-10
#200	≤ 2.5

There were small differences detected in the mix design, material gradations, and construction methods used by PCI during the summer of 1997 as compared to the test section constructed in 1995. The next several paragraphs will address these differences. The special provision for the 1995 dowel bar retrofit test section, entitled "Dowel Bar Retrofit", is located in Appendix A.

Gradation

The fine aggregate gradation for the 3U18 mix, used in the 1995 experimental test section, did not require #200 sieve nor did it require a #50 sieve for the coarse aggregate gradation.

Mix Design

The specified amount of fine aggregate required, per cubic yard of mix, during the construction of the 1995 test section was 1,318 lbs. The amount of coarse aggregate required, per cubic yard of mix, was 1,341 lbs.

Air Content

The air content specified during construction of the 1995 test section was 5.5% ± 1½%.

Water Reducer/Accelerator

Water reducer/accelerator was not specified during construction of the 1995 experimental test section.

Slump

During construction of the 1995 experimental test section, a slump test was not taken. Visual observation of the mix indicated an estimated slump of about 4 inches. A slump range of ½ to 1½ " was maintained by PCI during construction of the 1997 test section south of Fargo. It was recommended by PCI that a slump of less than 3/4" be used to prevent shrinkage in the mix.

Grout

During construction of the 1997 test section, grout consisted of cement, sand, and water was applied to the existing concrete walls prior to placement of the 3U18 mix. PCI believes the existing concrete will absorb some moisture from the grout instead of drawing moisture from the 3U18 patch mix itself. During construction of the 1995 test section, plain water was sprayed into the slot prior to placement of the 3U18 patch mix.

Curing Compound

During construction of the 1995 test section, the curing compound required was a water based material meeting the requirements of AASHTO-148. During construction of the 1997 test section, PCI applied an oil-based curing compound immediately after the final grouting. PCI believes the oil-based cure will aid in reducing shrinkage cracks.

Foam Core Boards

Core boards do not relate directly to the performance of the 3U18 patch mix, yet if constructed improperly, may obstruct proper placing and vibrating. During construction of the 1995 test section the core boards were 1/4" thick. During construction of the 1997 test section, PCI glued two 1/4" core boards together to get a final thickness of approximately 3/8" thick. PCI believed the thicker core board will stay upright when exposed to the stiffer 3U18 patch mix.

Construction

Materials and Research personnel arrived on site on the morning of July 31, 1997. Representatives from the Fargo District were present including the project engineer Kevin Gorder.

PCI was ready to place 3U18 patch mix material within ½ hour. The weather was cool, windy, and threatening rain. PCI commented prior to installation that dowel bar retrofit was very sensitive to moisture and that all operations should halt if rain was imminent.

Photo 1 on shows an overview of Project IM-8-029(006)000.

Photo 1 - Overview of the dowel bar retrofit operation.

Photo 2 shows the slots being sand blasted prior to placing of the caulk. □

Photo 2 - View of the sandblasting process.

After the sand blasting process was completed, a mechanical caulking dispenser was used to seal the existing transverse joint crack at the bottom and sides of the slot. Photo 3 Illustrates caulking being worked outward approximately ½" from the existing joint.

Photo 3 - View of caulking process.

Photo 4 is a close-up of the joint after the caulking process has been completed □

Photo 4 - Close-up view of the joint after the caulking is finished.

and photo 5 shows the core board fabrication process.

Photo 5 - View of the core board fabrication process.

Photo 6 shows the installed dowel bar and core board. Note the two 1/4" core boards that are glued together.

Photo 6 - View of the dowel bar and core board installed in the slot prior to the mix being placed.

Photo 7 on the next page shows a partial view of the batch mix unit on the left side of the picture. The contractor continuously batched small amounts of patch mix as the process went on. The contractor commented that he preferred using a batch mix unit as opposed to a mobile mixer unit because better control and consistency of the mix could be achieved. Prior to placement of the 3U18 patch mix, tests were performed for air, slump, and temperature. Cylinders were also taken of the mix. Several mixes had to be batched to obtain the desired air.

Photo 7 - View of the batch mix unit used to batch the 3U18 patch mix.

Photo 8 indicates the final slump was 3/4". The contractor commented that 3/4" or less was desired for this type of mix to aid in reducing shrinkage in the mix. Water reducers/accelerators were added to improve workability.

Photo 8 - View of a slump test being performed on the 3U18 mix.

As previously mentioned, the existing concrete grout served as an absorbing agent to fill any empty pore spaces in the existing concrete. The contractor believed it would reduce the chance for shrinkage cracks. Care was taken to apply the grout just before the placing of the patch mix. Photo 9 illustrates the grout composed of sand, water, and cement being broomed into the slot prior to placing the 3U18 patch mix.

Photo 9 - View of the grout being applied to the dowel bar retrofit slot.

After the patch mix was placed, it was then vibrated. Care was taken not to allow the core board to tilt or tip over into the mix. This was accomplished by one of the crew placing his foot directly over the core board while vibrating.

Photo 10 shows the patch mix being troweled and finished.

Photo 10 - View of the 3U18 patch mix being troweled and finished.

The contractor also likes to leave an abundance of patch mix in the slot. He commented that when it comes time to grind the slots, the creamier part of the mix can be eliminated. The grinding process also removed the excess core board extending above the road surface.

Photo 11 shows grout being applied just after the patch mix was finished. The contractor commented that placing the grout on the edge between the new mix and the existing concrete would also reduce the chance of shrinkage cracks.

Photo 11 - View of the grout being applied to a finished 3U18 patch mix.

Photo 12 shows the curing compound being applied to a finished slot. The contractor believed very strongly that the oil-based cure used here will do more to aid in reducing the chance for shrinkage cracks than a water-based cure.

Photo 12 - View of the oil based curing compound being applied to the finished and grouted 3U18 patch mix.

Evaluation

Materials and Research conducted the final evaluation of the dowel bar slots containing the 3U18 patch mix on September 10, 2002. Photo 13 shows an overview of dowel bar slots containing the 3U18 patch mix.

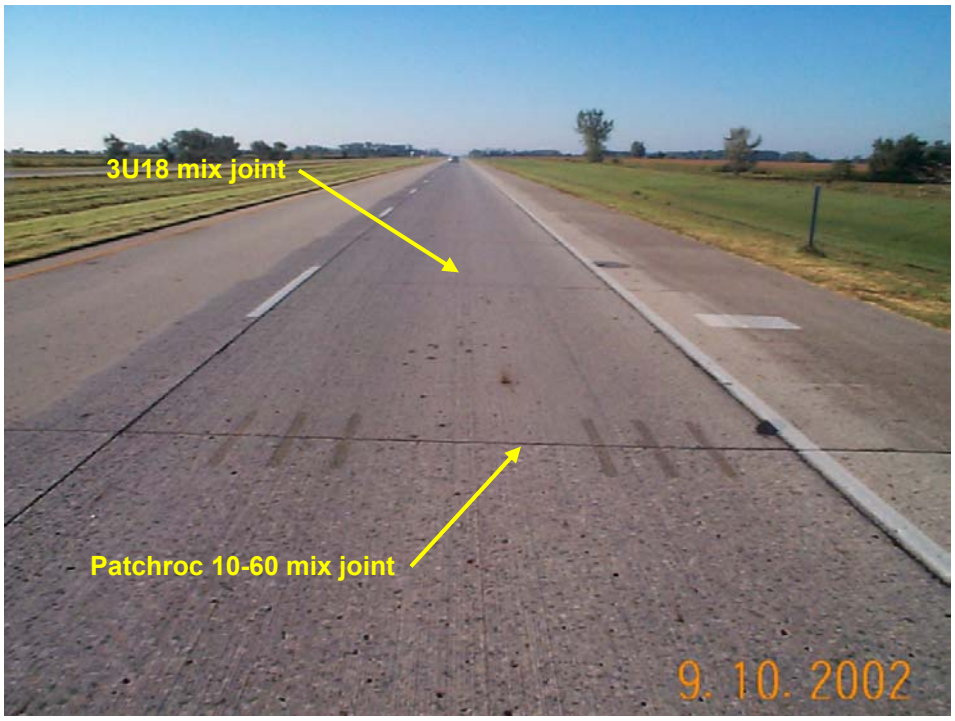


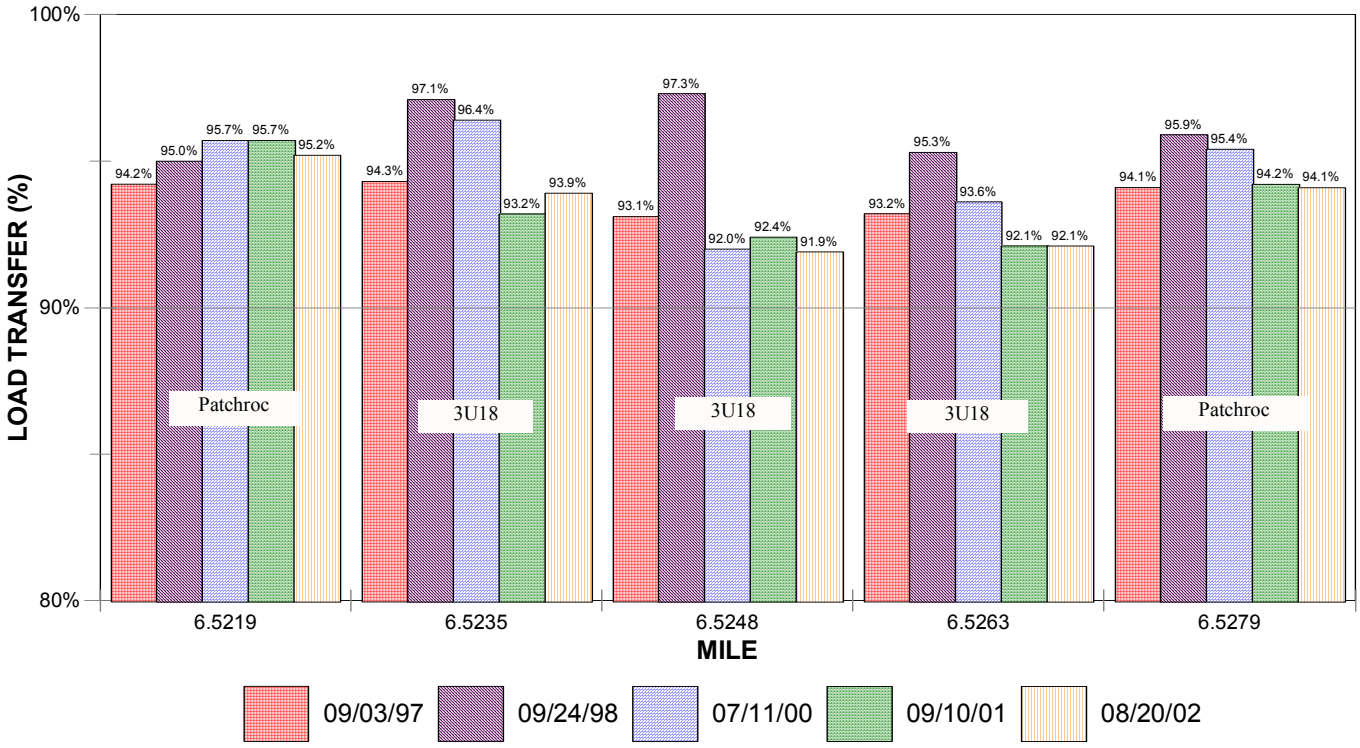
Photo 13 - Overview of dowel bar slots, 1st joint contains Patchroc 10-60.

Overall the 3U18 patch mix looked good with some visible cracks appearing at the surface. The cracks do not appear to be affecting the performance of the mix. Shrinkage cracks were detected within three months after placement of 3U18 patch mix in the 1995 test section that had affected the performance.

FWD analysis shows the 3U18 mix has an average load transfer efficiency of 92.6% while the Patchroc 10-60 mix has 94.7% load transfer efficiency after five years. Refer to the chart on the next page for the load transfer efficiency numbers.

INTERSTATE 29

LOAD TRANSFER-South Bound



The 3U18 mix has some hairline cracks between the existing concrete and the patch mix in some of the dowel bar slots. These cracks do not appear to be affecting the load transfer efficiency as dictated by an average load transfer of 92.6%. The other distress that is occurring in the 3U18 mix is minor aggregate popouts. The surrounding pavement also has popouts.

One very noticeable difference between the 3U18 mix and the Patchroc 10-60 mix is the aesthetics of the mix. Photo 13 shows one the Patchroc joints and then the 3U18 mix joints. The 3U18 mix joints are virtually undetectable. Photos 14, 15, and 16 shows the joints with the different patch mix materials.

Photo 14 - Dowel bar slots containing Patchroc 10-60.

Photo 15 - Dowel bar slots containing 3U18.

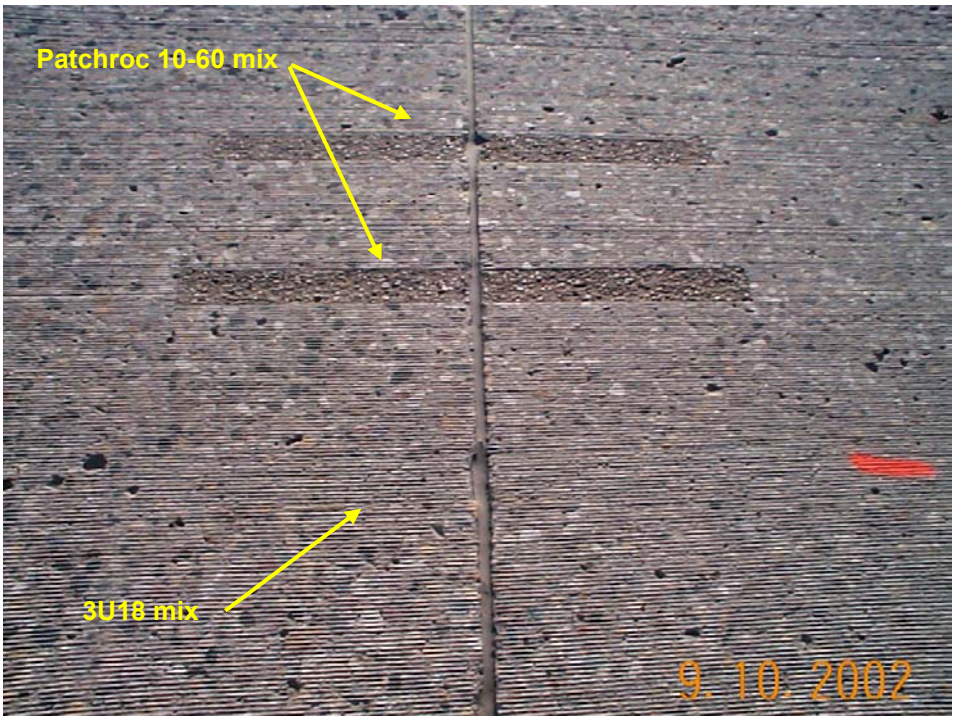


Photo 16 - Comparison of the mixes side by side.

The durability of the 3U18 mix also appears to be better than the Patchroc 10-60 mix. Refer to photo 17.

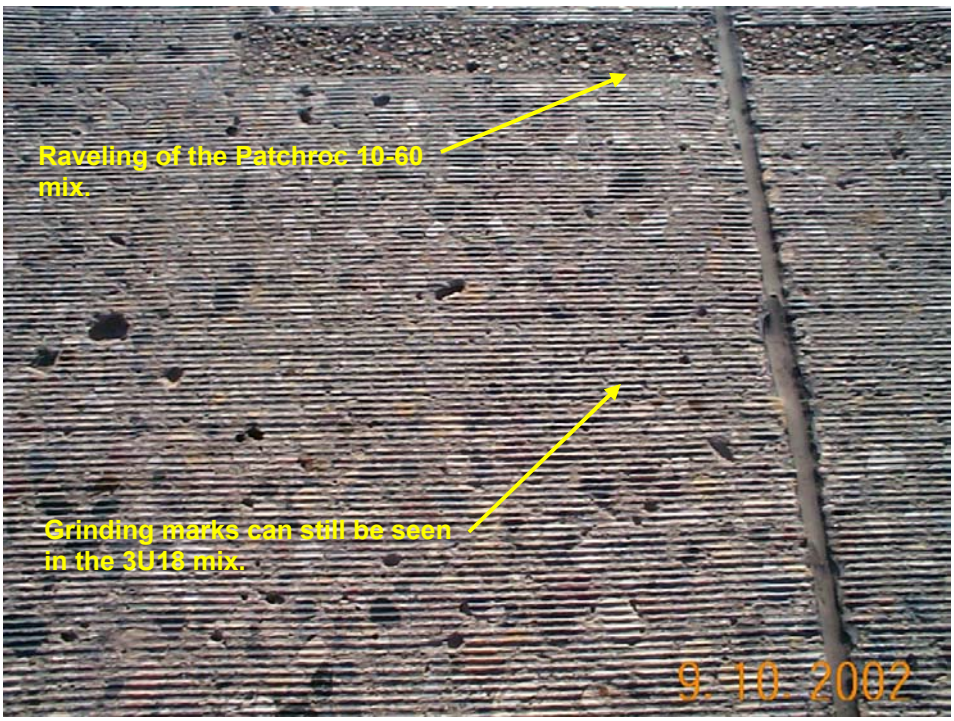


Photo 17 - Durability of both mixes.

As can be seen in photo 17, the Patchroc 10-60 is raveling at the surface while the grinding marks can still be seen in the 3U18 mix.

Photo 18 - Close up view of the Pacthroc 10-60 mix shown in photo 17.

Summary

Construction of the dowel bar retrofit test section containing 3U18 Minnesota specified patch mix material went well. The 1997 test section has slight variations in aggregate gradations, mix design and construction method as opposed to the 3U18 patch mix used in the previous 1995 dowel bar retrofit test section. Evaluations have shown the Minnesota specified 3U18 patch mix material is performing well. Recent FWD results show load transfer across the joints to be 92.6%. Adjacent dowel bar slots containing Patchroc 10-60 patch mix material show load transfers of 94.7%. The most notable distress in the Patchroc mix is there is raveling in every slot which has not been observed in the 3U18 slots.

Recommendation

The 3U18 mix has shown good load transfer efficiency with good durability. It is recommended that the 3U18 mix used in this research project can be used in other NDDOT projects provided strict adherence to the mix design and construction procedures can be followed. If this can not be achieved, the load transfer efficiency and durability characteristics will suffer.

Appendix A

4-10-95

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION

DOWEL BAR RETROFIT

PROJECT IM-6-029(022)186

June 16, 1995

DESCRIPTION

This work consists of retrofitting epoxy-coated dowel bars into existing concrete pavement.

MATERIALS

1. Curing Compound. The curing compound shall be a liquid membrane-forming compound that conforms to the requirements of AASHTO M-148 (ASTM C 309) Type 1-D or 2, Class A or B.

2. Dowel Bars. The Dowel bars shall be plain, round bars fabricated from steel meeting AASHTO M-31, M-42, or M-53. Dowel bars shall be cut to the required length and cleaned to remove all cutting burrs, loose mill scale, rust, grease, and oil. The bars may be sheared providing the deformation of the bars from true round shape does not exceed 0.04 inch in diameter or thickness, and shall not extend more than 0.04 inch from the sheared end.

   Dowel bars shall be epoxy-coated 100% on all surfaces. The epoxy coating shall be in accordance with AASHTO M-284. The dowel bars shall also be shop coated with a bond breaking release agent. The bond breaking release agent shall be a black, non-diluted, Tectyl 164 as manufactured by Valvoline Oil Co. The dowel bars shall be installed and covered with patch material within 6 months of the delivery date.

   The dowel bars shall have tight fitting end caps made of nonmetallic materials that allow for 1/4 inch movement of the bar at each end. The Contractor shall submit sample end caps to the Engineer prior to use.

3. Caulk. The caulk for sealing the existing transverse joint crack at the bottom and sides of the slot shall be any commercial caulk designed as a concrete sealant that is compatible with the patch material being used.

4. Foam Core Board. The foam core board shall be 1/4 inch thick, constructed of closed cell foam, and be faced with poster board material on each side.

5. Patching Material. Two types of patch material will be used on this project. One-half of the project will be completed using a

patch mix made from local materials and the other half will be completed using a commercial patch mix.

a. "Concrete Patch Mix Type A" shall be a mix prepared using the following mix design:

Cement	850 lbs
Water	295 lbs
Sand	1318 lbs
Course Aggr.	1341 lbs.

The cement used shall be a Type I, IA, II, or IIA cement meeting the requirements of Section 804.01.

Air-Entraining Admixture shall meet the requirements of Section 808.01. The air content of the mix shall be maintained at 5.5 percent, plus or minus 1.5 percent.

Fine aggregates shall meet the requirements of Section 816.01.

Course aggregate shall meet the requirements of Section 816.02. The gradation for the course aggregate shall be:

Sieve	% Passing
3/8"	100
#4	70-95

b. "Concrete Patch Mix Type B" shall be Patchroc 10-60, Five Star Highway Patch, Burke 928 Fast Patch or an approved equal.

6. Chairs. The chairs for supporting and holding the dowel bars in place shall be completely epoxy coated according to Section 836.02B, or made of nonmetallic material.

CONSTRUCTION REQUIREMENTS

The Contractor shall install the dowel bars in the existing concrete pavement as shown in the Plans and according to the following specifications:

1. Slots shall be saw cut in the pavement to the depth required to place the center of the dowel at mid-depth in the concrete slab. Multiple saw cuts parallel to the centerline may be required to properly remove material from the slot.
2. Jack hammers used to remove the concrete shall not be larger than the 30 pound class.

3. All exposed surfaces and cracks in the slot shall be sand blasted and cleaned of saw slurry and loose material before installing the dowel. All loose material will be disposed of by the Contractor off of the highway right-of-way.

4. Dowel bars shall be placed in a chair that will provide a minimum of 1/2 inch clearance between the bottom of the dowel and the bottom of the slot. The dowel bar shall be placed to the depth shown in the plans, parallel to the centerline, and parallel to pavement surface of the lower panel at the transverse joint, all to a tolerance of 1/4 inch. The chair design shall hold the dowel bar securely in place during the placement of the patch mix.

5. The contractor shall caulk the existing transverse joint crack at the bottom and sides of the slot as shown in the Plans. The transverse joint crack shall be caulked to provide a tight fit for the foam core board at the transverse joint and to prevent any of the patch mix from entering the crack at the bottom or the sides of the slot.

6. The dowel bar shall be placed through the foam core board at the specified location. The dowel bar shall be placed so a minimum of 7.0 inches is placed on either side of the transverse joint. The foam core board shall be capable of remaining in a vertical position and tight to all edges during the placement of the patch mix. If for any reason the foam core board shifts during the placement of the patch mix, the work shall be rejected and replaced at the Contractor's expense.

7. The existing concrete surfaces inside the slotted area shall be moistened with a hand sprayer immediately prior to placing the patch mix.

8. The patch mix shall be placed into the slot and vibrated with a small hand held vibrator to insure that the patch mix completely surrounds the dowel bar.

9. The surface of the filled area shall be cured using a curing compound that meets the requirements of AASHTO M-148.

10. The transverse joint shall be maintained by sawing the joint through the patched area within 24 hours after placement of the patch mix. The joint shall be sawed and sealed as shown in the plans

METHOD OF MEASUREMENT

Dowel Bars will be measured by each dowel bar installed and accepted by the Engineer.

BASIS OF PAYMENT

Payment for "Dowel Bar Retrofit - Type A" shall be full compensation for all labor, equipment, and materials necessary to complete the work using Type A patch mix.

Payment for "Dowel Bar Retrofit - Type B" shall be full compensation for all labor, equipment, and materials necessary to complete the work using Type B patch mix.

Payment will be made at Contract Unit Prices for the following:

Pay Item	Pay Unit
Dowel Bar Retrofit - Type A	Each
Dowel Bar Retrofit - Type B	Each

Appendix B

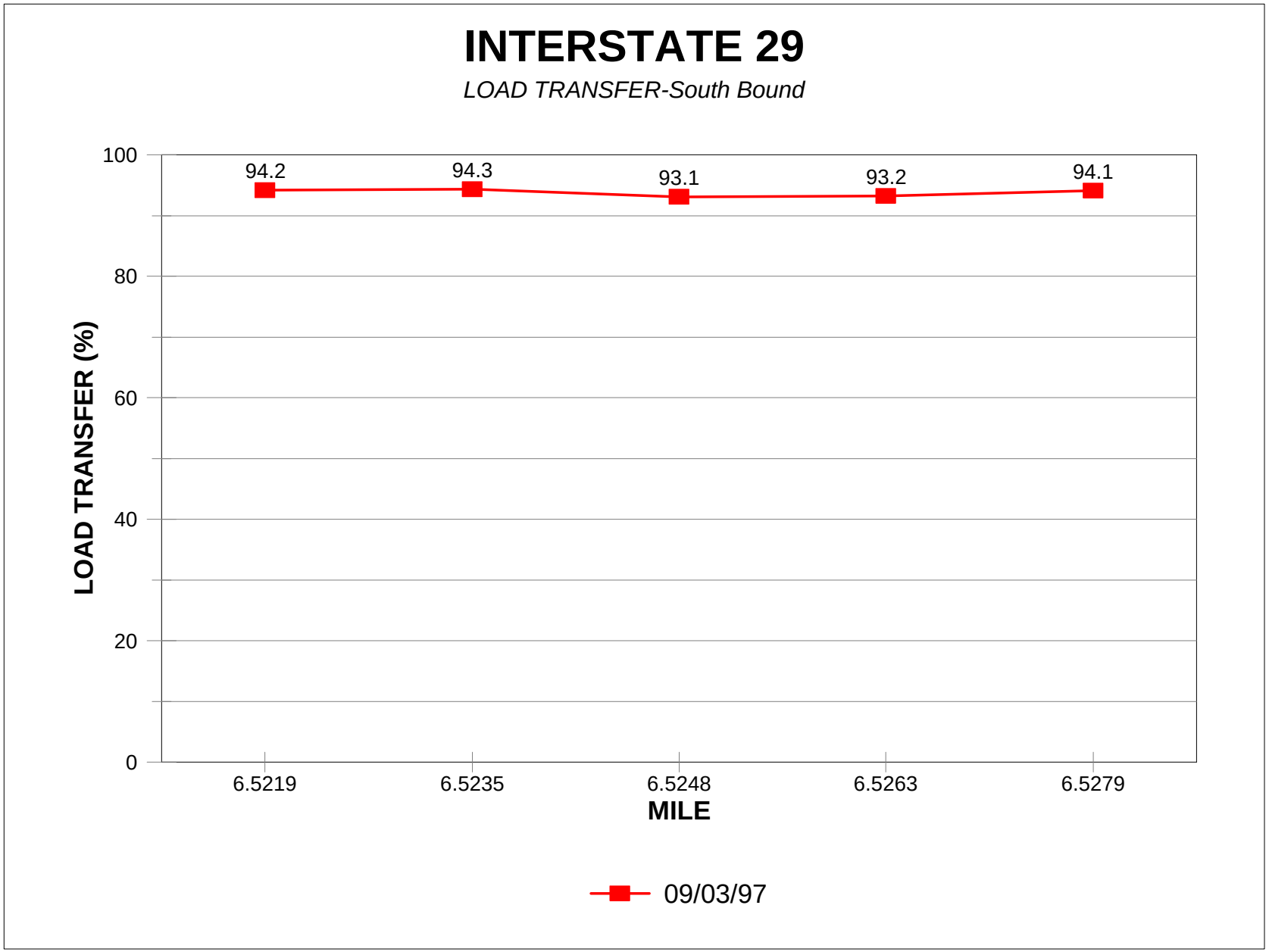
INTERSTATE 29

09/03/97

PROJ AVE

STD DEV

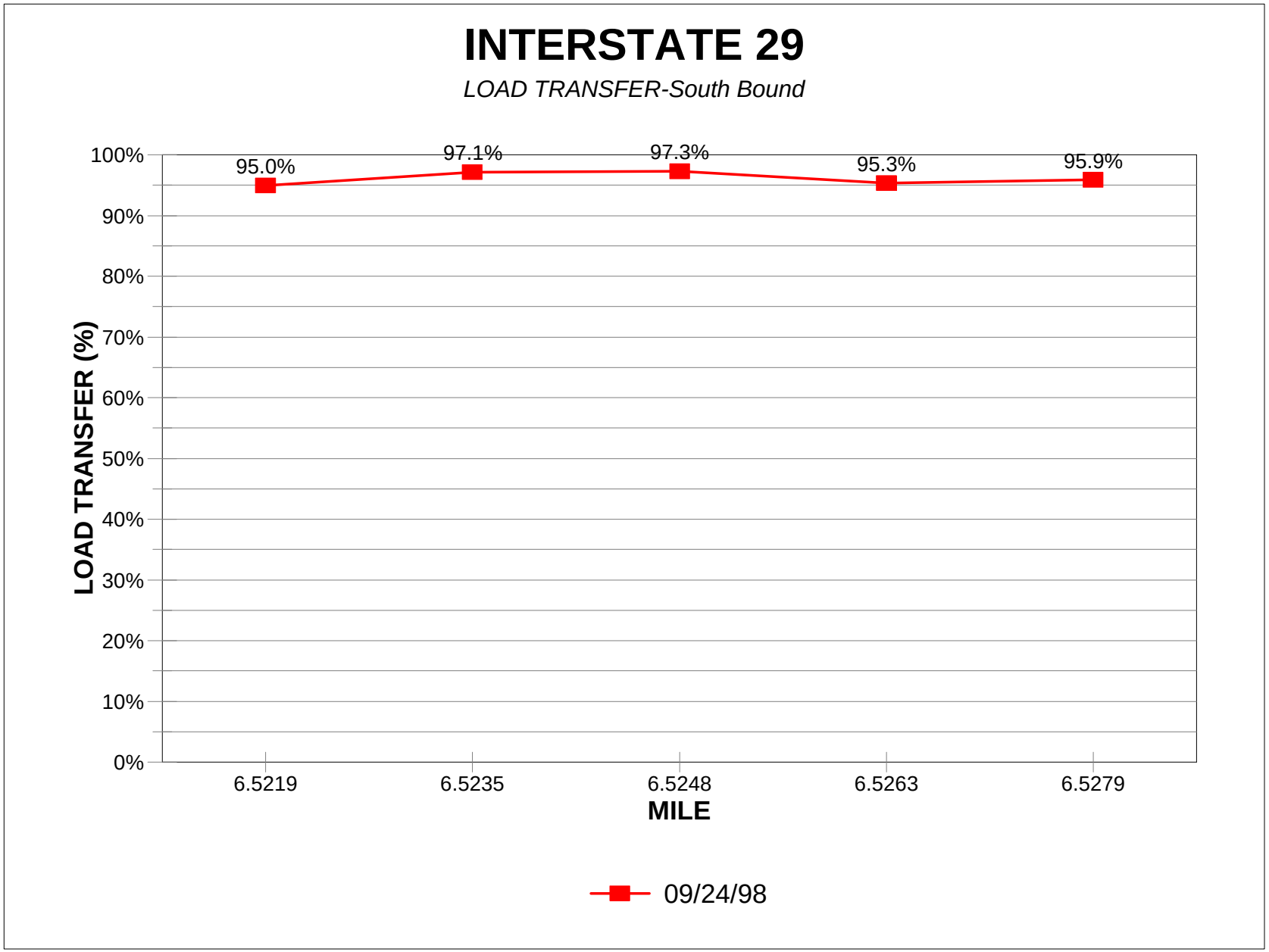
Chainage	#1 DEF	#2 DEF	LT	%
6.5219	16.89	15.91	0.942	94.2
6.5235	14.68	13.85	0.943	94.3
6.5248	14.42	13.42	0.931	93.1
6.5263	17.71	16.51	0.932	93.2
6.5279	19.41	18.27	0.941	94.1


INTERSTATE 29
LOAD TRANSFER-South Bound
100
80
60
40
20
0
LOAD TRANSFER (%)
94.2
94.3
93.1
93.2
94.1
6.5219
6.5235
6.5248
6.5263
6.5279
MILE
09/03/97

INTERSTATE 29

	09/24/98		Average
PROJ AVE	96.1%	3U18 Mix	96.6%
STD DEV	1.05%	Patchroc	95.4%

Chainage	#1 DEF	#2 DEF	%
6.5219	13.66	12.97	95.0%
6.5235	9.62	9.34	97.1%
6.5248	11.50	11.19	97.3%
6.5263	14.78	14.09	95.3%
6.5279	13.77	13.20	95.9%

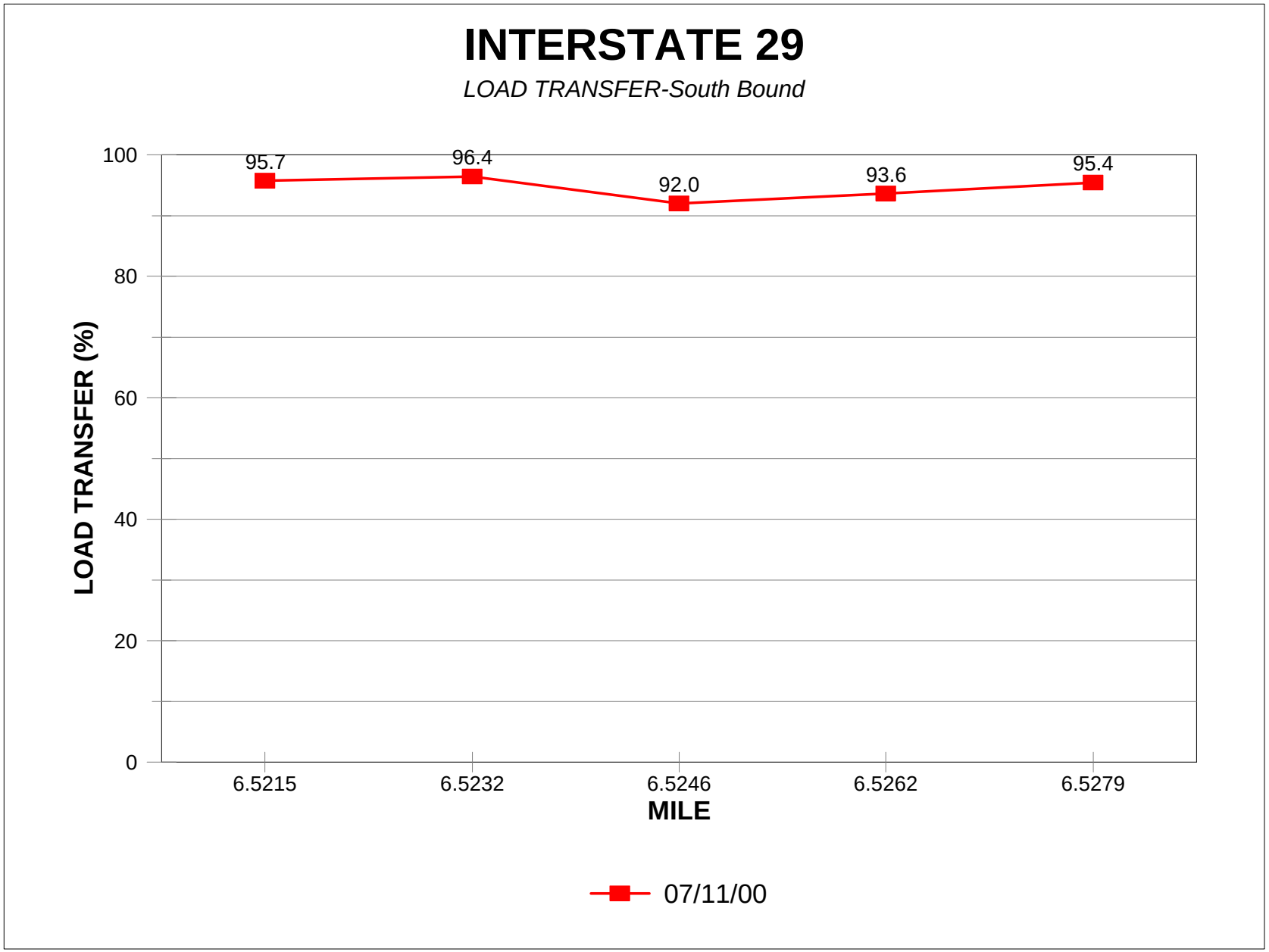

INTERSTATE 29
LOAD TRANSFER-South Bound
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
LOAD TRANSFER (%)
95.0%
97.1%
97.3%
95.3%
95.9%
6.5219
6.5235
6.5248
6.5263
6.5279
MILE
09/24/98

INTERSTATE 29 - LOAD TRANSFER

07/11/00

MILE	AVE	STD DEV
6	94.6	1.8

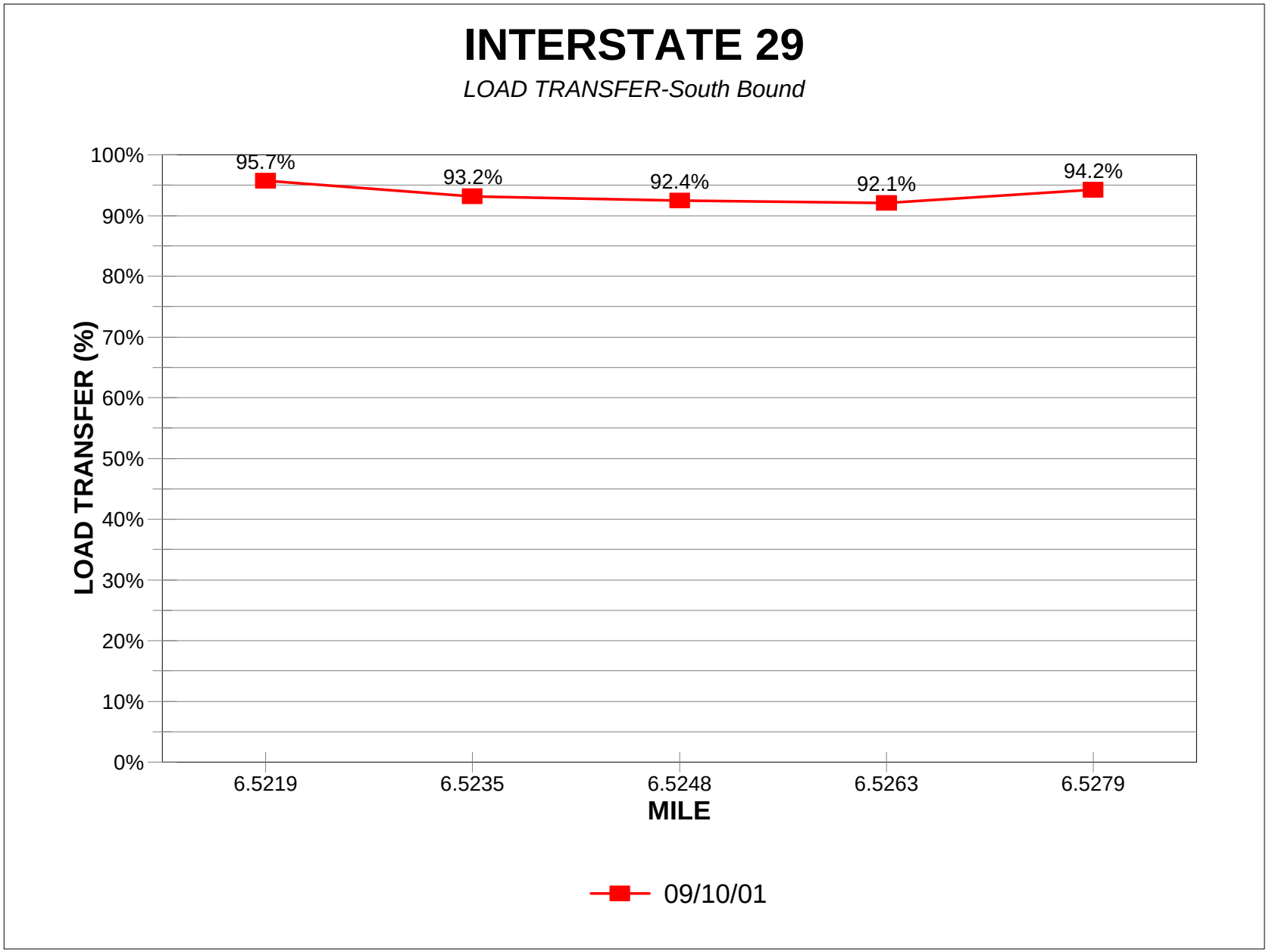
Chainage	#1 Def	#2 Def	LT	%
6.5215	35.1	33.6	0.957	95.7
6.5232	33.3	31.2	0.964	96.4
6.5246	33.7	31.0	0.920	92.0
6.5262	32.9	30.8	0.936	93.6
6.5279	30.4	29.0	0.954	95.4


INTERSTATE 29
LOAD TRANSFER-South Bound
LOAD TRANSFER (%)
100
80
60
40
20
0
95.7
96.4
92.0
93.6
95.4
6.5215
6.5232
6.5246
6.5262
6.5279
MILE
07/11/00

INTERSTATE 29

	09/10/01			Average
PROJ AVE	93.5%		3U18 Mix	92.5%
STD DEV	0.0		Patchroc	95.0%

Chainage	#1 DEF	#2 DEF	%
6.5219	19.82	18.97	95.7%
6.5235	20.39	19.00	93.2%
6.5248	20.93	19.34	92.4%
6.5263	20.07	18.48	92.1%
6.5279	19.95	18.80	94.2%


INTERSTATE 29
LOAD TRANSFER-South Bound
LOAD TRANSFER (%)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
95.7%
93.2%
92.4%
92.1%
94.2%
6.5219
6.5235
6.5248
6.5263
6.5279
MILE
09/10/01

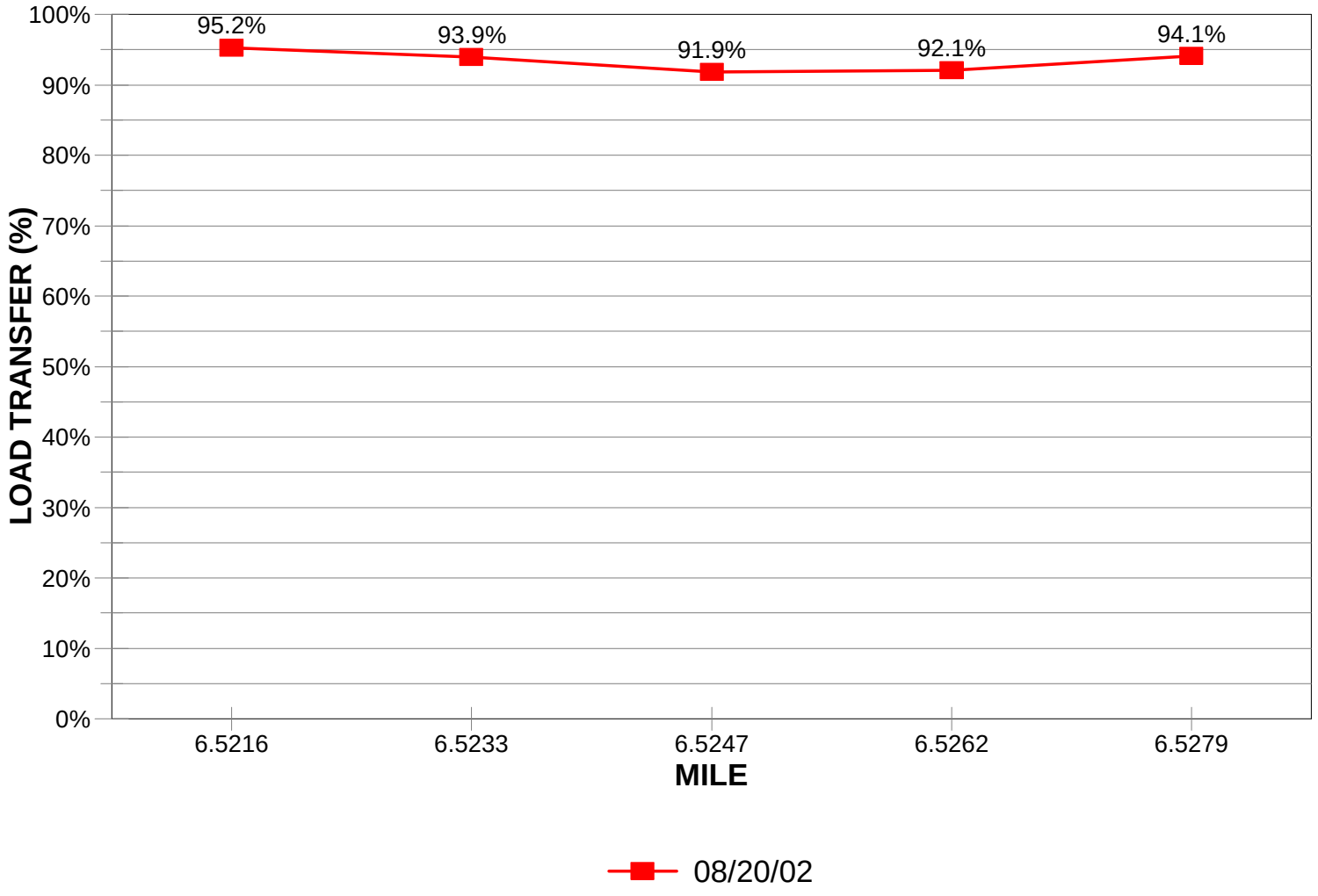
INTERSTATE 29

	08/20/02			Average
PROJ AVE	93.4%		3U18 Mix	92.6%
STD DEV	0.0		Patchroc	94.7%

Chainage	#1 DEF	#2 DEF	%
6.5216	27.15	25.86	95.2%
6.5233	26.80	25.17	93.9%
6.5247	27.63	25.38	91.9%
6.5262	30.06	27.68	92.1%
6.5279	29.09	27.38	94.1%

INTERSTATE 29

LOAD TRANSFER-South Bound



INTERSTATE 29

LOAD TRANSFER-South Bound